EARTH SCIENCE TECHNOLOGY OFFICE

Earth Science System/Trade Studies

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ESTO

- Earth Science System/Trade Studies constitute an integral and critical part of ESTO's overall thrusts to develop and infuse advanced technologies into the future Earth Science missions
- Studies evaluate science and applications Capability Needs and identify technology requirements to satisfy them, and compare merits of competing implementation options
- Studies outputs include mission analyses, costs/benefits analyses, technology readiness assessments, and development risk assessments among others
- Studies may define overall architectural requirements as well as system, subsystem and component level requirements to fulfill science and applications measurement objectives

FY 98 Studies

- NASA centers overwhelmingly supported ESTO solicitation and selection of FY 98 Studies
  - An expedited selection process used, which was fully coordinated with YF, YS, YO and IPO
    - Proposals requested - Feb/March
    - Proposals coordinated with STCB/Users - March/April
    - Final cost/schedule data received - May
    - Studies selected - June
    - Monthly status briefing - July/December
    - Final reports due - December
- 9 study areas were selected with the following funding provided to centers

– LaRC	$1060 k	- GSFC	255 k
– JPL	930 k	- MSFC	200 k

FY 98 Studies

- Studies selected were consistent with NRC recommendations
  - Wideband, high data rate communications; precisely controlled space structures; microelectromechanical systems for space; space nuclear power systems*; low cost, radiation resistant memories and electronics; and extraction and utilization of extraterrestrial resources*
- Studies were also consistent with OCT emphasized strategic technologies
  - Advanced miniaturization, intelligent systems, compact sensors and detectors, self-sustaining human support*, deep space systems*, and intelligent synthesis environment

* - Not applicable to ES

FY 98 Studies

- Lidar Technologies
  - Investigate various means of combining the data available from star trackers, INS, and GPS, with quick on board processing of the surface return signal from the Doppler lidar to accomplish optimum laser shot pointing control, pre-shot pointing direction knowledge/prediction, and post-processing pointing direction knowledge.
  - Identify the possible degradation and failure modes that may occur during launch or during on orbit operation for an operational space-based CDWL instrument. Study optical techniques to preserve CDWL alignment and optimum operation during occurrence of degradation modes by mitigating the effect. The adaptive optics technology will be also investigated.
  - Compare the rotating wedge scanner versus the rotating telescope approach to obtaining a conical scan pattern. Compare and trade the continuous rotation versus the step stare rotation approaches to achieving conical scanning. Compare and trade unidirectional versus bi-directional capability for the step stare approach. Consider the aspects of optical design, lidar alignment, wavefront quality, polarization requirements, mass, volume, cost, pre-launch testing, and angular momentum impulses on the spacecraft.

FY 98 Studies

- Lidar Technologies
  - A high energy, UV solid state laser is needed for the global measurement of ozone from space. Differential Absorption Lidar (DIAL) systems have shown excellent range-resolved capabilities for simultaneous ozone and aerosol profile measurements. The laser transmitter must be able to operate from a space based platform and have an operational lifetime of three years.
  - The Office of Earth Science has established requirements to globally measure with high vertical and horizontal resolution the distribution of clouds and aerosols, allowing improved characterization of the role of aerosol and cloud in global climate. Establish and document the technology development requirements that enable and enhance this remote sensing measurement from space on a global scale.
  - Tropospheric wind measurements in the form of accurate, low bias, vector wind profiles are the highest priority requirements. Identifying the technical impediments and perform the system trades associated with producing a wind lidar free-flyer precursor to an operational instrument.

FY 98 Studies

- Multi/Hyperspectral Remote Sensing
  - Relative merits of different technological approaches to gathering and interpreting data about the Earth's surface and atmosphere will be evaluated. Technologies that can reduce the cost and mass/volume envelopes and improving science return will be emphasized. The study will be primarily concerned with multi/hyperspectral systems, with a wide field of view and no moving parts.
  - Determine the extent to which remote sensing can be used to measure carbon sequestration rates. And, compare how well changes in land use, land cover and bio-mass content can be measured by imaging/ interferometric SAR, laser altimetry/lidar and multi-spectral scanning.
  - There is a critical need for both high spatial resolution and multispectral detector and focal plane array capability in the thermal IR region. Assess key long wavelength infrared focal plane arrays technology options and compare their merits and applicability to future thermal IR instruments.

FY 98 Studies

- Advanced Microwave Radiometry
  - Microwave radiometry and scatterometry represent the preferred detection techniques for many earth science applications such as for soil moisture, polar ice, ocean surface salinity, ocean surface temperature, ocean surface wind velocities, and some atmospheric sounding applications. However, spatial resolution at microwave frequencies requires much larger effective apertures, making it a challenge to achieve the desired resolution with limited payload size and cost. Examine the techniques and technology options to achieve the desired system performance with low-mass deployable structures. System, subsystem, and device level performance requirements will be defined.
  - Synthetic aperture radiometry offers advantages in many microwave radiometry applications. A reference model for science missions will be developed and technology objectives will be established. System, subsystem, and device level performance requirements will be defined, and detailed technology targets will be established to enable planning and prioritization.

FY 98 Studies

- Advanced Microwave Radiometry
  - Global mapping of vegetation canopy characteristics is of prime importance for assessing key determining factors in climate models, terrain use, and ecological studies. The objectives are: 1) to conduct a comparison of laser profilometry and interferometric-polarimetry accuracies in determining vegetation canopy parameters over a common site; and 2) based on the results obtained, to assess the feasibility of using interferometry for global vegetation studies, and to design follow-on experiments.
  - Assess the feasibility of combining scatterometric and along-track interferometric ocean measurement techniques in terms of system design constraints and scientific tradeoffs. The goal is a system that will make ocean measurements of both vector surface winds and vector surface currents simultaneously providing a unique data set valuable for both upper ocean-circulation and air-sea interaction studies. The study also evaluates several system design options and determine the tradeoffs involved, both in terms of system complexity and scientific value. Error-analyses and mass/cost estimates will accompany the system design(s).

FY 98 Studies

- GPS Surface Reflection
  - The recent discovery of GPS signals reflected from water and large metal objects has given rise to a large number of suggested space and aircraft/balloon applications. Some of these applications are all-weather, day-night wetlands and flood zone mapping, ionosphere TEC map supplements, sea-state and windfield determination and imaging. Identify requirements for antenna size for space altitudes, (increased S/N), electronically phased LBand antennas (for specular point targeting) improved correlator technology (for L1, L2 cross-correlation) and Doppler processing hardware/software (for imaging.)
  - Preliminary analysis to determine the scope of applications and technology requirements for the GPS bistatic systems and technology; Perform more detailed analytical studies to assess the anticipated SNR from space with different types of antennas; and Analyze microGPS airborne data to determine the feasibility of modifying internal GPS instrument software to enable optimal detection of and tracking of reflected signals from the ocean.

FY 98 Studies

- Tropospheric Measurements
  - A double-etalon Fabry-Perot interferometer (FPI) will enable direct observation of tropospheric ozone (and other tropospheric trace species) using a compact, rugged sensor with a minimum of mechanical complexity. This concept will enable a space-based high spectral resolution measurement capability with significant improvement in spectral resolution and instrument volume & mass ratios verses comparable current or planned instruments. Develop a conceptual instrument design and related optical, mechanical, and thermal analyses that define the technical requirements of major components of a compact, space-based, high spectral resolution FPI for measuring tropospheric ozone.
  - Develop advanced mission concepts for the Active Tropospheric Ozone and Moisture Sounding applications. Assess the state of current microwave hardware in the desired frequency range; Assess the feasibility and practicality of advancing the state of current technology to meet scientific measurement needs; evaluate expected performance after development and compare against alternative techniques, if any; and If indicated by above analysis, develop a strawman instrument conceptual design and a high-level development plan.

FY 98 Studies

- Geo Missions
  - Develop the technology requirements for building a staring (i.e. non-scanning), UV-visible, geostationary imaging radiometer for trace gas and aerosol measurement. Results will define the instrument parameters including the required array sensitivity, integration times, filter bandwidth and out-of-band blocking, and operating temperature and identify emergent enabling technologies,
  - Evaluate technology for extended area, low power, low noise, high resolution, moderate temperature, infrared focal plane arrays suitable for extended space missions. Large format focal plane arrays with passive staring sensor capability provides continuous, wide area remote sensing of Earth environment for the purpose of observing atmospheric constituents, circulation, and aerosol dynamics. The objective is to develop high sensitivity sensor capability requiring minimal cooling and with long life, low cost, and compact configuration. Requirements for prototype devices will be defined.

FY 98 Studies

- Geo Missions
  - Assess the feasibility, constraints, and challenges (e.g., cost-perfomance options/tradeoffs) of conducting coordinated quasi-geostationary observations from Molniya or similar (e.g., highly inclined geosynchronous) orbits; assess the advantages and/or disadvantages of such observations vis-à-vis other alternatives (e.g., LEO constellations); and assess opportunities for implementation of new advanced observational (e.g., ultra-lighweight optics, micro-miniaturization) and communication (e.g., direct broadcast to aircraft) technologies in conjunction with such high polar orbits (e.g., new requirements vs. performance metrics).

FY 98 Studies

- Mid-Earth Orbit (MEO) Applications
  - A series of inexpensive, near-Earth missions in the so-called Middle Earth Orbit (MEO) environment are planned. These missions are intended as to provide cheap, reliable access to the MEO environment (defined here to be between 1000 km and 20,000 km). The primary objectives of this study are to identify: 1) the flight of specific experiments to measure in-situ parameters of importance to Earth Science that require a MEO trajectory; 2) experiments flown primarily to evaluate their behavior in the radiation environment but that can be used in a secondary role to sense data of relevancy to Earth Science; and 3) cross-correlation experiments valuable to Earth Science.

FY 98 Studies

- High Data Rate Instruments and Communications
  - Assess data-rate requirements for anticipated instruments including Hyperspectral imaging in the visible and infrared, SAR and next generation radar systems, Imaging lidars, Interferometers, and others; Return on investment analysis of system options supporting high-data-rate instruments including On-board processing vs. high bandwidth downlinks, Data compression vs. raw data downlink, Real-time data compression vs. non real-time data compression, Comparison of various on-board data systems, Comparison of various communications downlink options including Ka-band and optical communications, phased array antennas, etc.; and Technology readiness assessment of enabling technologies and systems.
  - Assess the feasibility of employing a Ka-band link in conjunction with the use of phased array antennas. Ka-band offers the advantage of high data rates due to the increased antenna gains at both ends of the link. In addition an electronically scanned phased array antenna would ameliorate the severe spacecraft pointing requirements concomitant with the use of a high gain antenna.

FY 98 Studies

- High Data Rate Instruments and Communications
  - Investigate the advantages of using commercial-off-the-shelf (COTS) components for the real time processing of future synthetic aperture radar (SAR) systems. It will be demonstrated that for a given computational requirement, the total size, weight, and power (SWAP) can be reduced, and the real time computations are more efficiently performed on a heterogeneous COTS-based platform. Finally, it will be shown that such platform can lead to easy system reconfigurability and upgradability because COTS components are based on industry standardization and open-system architecture.

FY 98 Studies

- Autonomous Formation and Constellation Flying
  - Develop closed loop navigation and attitude control approaches for multiple, cooperating spacecraft; development of formation flying and virtual platform control strategies (formation initialization, formation maintenance, formation reconfiguration); and formation flying simulation and testbed environment to support the development and validation of control strategies
  - Conduct communication system requirements/crosslink system analysis; identify scenarios; define requirements; evaluate technical approaches; and conduct trades for integrated inter-spacecraft data transfer and relative navigation performance requirements.

Future Planning

- In conjunction with alternative resources, additional studies may be considered for funding based on results of FY 98 Studies and which are consistent with the Easton recommendations and long term ES Vision
- LaRC proposed Space Technology R&D IDIQ mechanism may be considered for solicitation and selection of FY 99 studies
- NRA for FY 00 and beyond studies being considered